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Disclaimer

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Abstract

The effectiveness of a modified insecticide strategy and a cultural technique for controlling rice water weevil (RWW) was evaluated in field studies. Two insecticides, were registered (in 1999) for application after field flooding. Application of a pre-plant insecticide to the field margins was the long-time standard method for controlling RWW. A key question regarding these newly-registered products, Dimilin® 2L and Warrior® 1EC, is if they will provide efficacious RWW control when applied only to the field borders compared with applications to the entire field. Averaged over seven locations, no differences were seen in RWW larval control with Dimilin used with the border method compared with the entire field treatment. However, the cool spring weather influenced the RWW population dynamics and therefore larval control with both methods was somewhat less than desired. Results with Warrior applied to field borders were similar. Plots treated with Dimilin outyielded untreated plots by ~800 to 1400 lbs. Previous small plot research indicated that lower RWW larval populations occurred during the growing season in areas that were winter-flooded compared with non-flooded areas. This research in 1999 was extended to grower fields; at five of the eight paired comparisons there were significantly fewer RWW larvae (up to 80%) following winter-flooding compared with fields not winter-flooded.

Executive Summary

The efficacy of a modified insecticide strategy and a cultural control technique on rice water weevil (*Lissorhoptrus oryzophilus* Kuschel) was evaluated in field studies. The specific objectives of this work were 1.) to investigate the effectiveness of post-flood border insecticide treatments for the management of rice water weevil larvae in California rice and 2.) to demonstrate the effectiveness of a cultural technique, winter rice field flooding, for the management of rice water weevil in California rice. Preplant applications of a granular insecticide were the standard method of controlling rice water weevil in California. Registration of the insecticide used for this treatment, Furadan, is scheduled for cancellation. Since 1991, the registration has been under scrutiny and 2000 has been designated as a year to clean-up existing inventory of this product. Two products, Dimilin® 2L and Warrior® 1EC, used as post-flood treatments were registered in 1999. Economic rice water weevil populations generally only occur in the first 30-50 feet of the basins adjacent to the levees. Therefore, the standard application method with Furadan is to apply the insecticide only to this area. This method provides effective control and has the positive attributes of reducing the amount of insecticide used, cost, potential exposure, etc. A key question regarding the use of post-flood products is if they will provide efficacious rice water weevil control when applied only to the borders of the basins compared with applications to the entire basins. The optimal timing for these post-flood products is approximately the 3 rice leaf stage. There is very little foliage leaf area to intercept the insecticide at this time; most of the insecticide goes into the water. With a border treatment and having only ~15% of the basin treated (varies with size and shape of basin), the mixing of treated and untreated water may dilute the insecticide concentration and render the application ineffective. Studies for this objective were conducted in ten grower fields in 1999. Data were collected following insecticide application (whole vs. border applications with various rates) on the percentage of rice plants with adult damage, larval population magnitude per 4 inch diameter core sample, and rice grain yield (small plot hand harvest and commercial harvest). Across seven sites, averages were 3.25 rice water weevil per core sample (untreated), 1.45 (Furadan), 2.03 (Dimilin full basin), and 2.04 (Dimilin border treatment). Control efficacy was generally good in the first larval sample date (~7 weeks after seeding and ~4 weeks after application) and poor in the second larval sample date (~9 weeks after seeding). The spring and early summer in 1999 were characterized by cool temperatures. These conditions were optimal for rice water weevil adult survival and for a prolonged oviposition period (related studies conducted by my laboratory verified this). This resulted in adult populations and, in several cases, significant oviposition after the Dimilin or Warrior application had dissipated. These late deposited eggs in treated and untreated plots were manifested as poor control in the later sampling period. However, in all cases, grain yields were higher in the Dimilin treated areas than in the untreated areas (1000 to 2200 lbs/A for hand harvests and 800 to 1400 lbs./A for commercial harvests). There were no significant differences between the yields with the Dimilin full basin vs. border treatments. The reason for these apparent contrasting results (moderate larval control but excellent protection of yield) may be that the early larval infestation (when the plant is probably most susceptible to damage) was effectively controlled and that the later arising larvae do not appreciably effect the plant. Once the plant and root system have obtained significant size, some root pruning by rice water weevil larvae may not be important in terms of yield reduction. The point (plant growth stage) where this insect goes from a pest to non-pest is unknown. Results were generally similar for Warrior treated areas although studies were conducted at only three locations. In summary, it is significant that the border applications of Dimilin or Warrior appear to work as well as full basin treatments. However, it also appears that during years with prolonged oviposition, multiple application of these products may be needed for optimal larval control. Cultural controls are presently also used, in part, to manage rice water weevil populations. Previous small plot research has shown that lower rice water weevil larval populations occur during the growing season in areas that were winter-flooded compared with non-flooded areas. This research in 1999 was extended to larger plots and to grower fields. Seven locations, comparing rice water weevil populations in paired fields (one winter-flooded and one not winter-flooded), were examined. In addition, research was continued at a large plot research site. Rice plants were evaluated for rice water weevil adult feeding incidence and larval population density. Results from the large plot research site showed a 62.5% reduction in rice water weevil larval populations in winter-flooded basins compared with the non winter-flooded basins. For the other seven grower field sites, overall there were no differences among the sites with regards to average number of overwintering adults and rice water weevil per core sample (2.2 vs. 2.8 RWW per core sample). Percentage scarred plants were reduced by the winter-flooding. However, in four of seven sites, a significantly lower number of larvae was found in the winter-flooded plots compared with the nonflooded. plots. The larval population reduction due to winter-flooding was as high as 80% and was present in two sites that had very high larval populations. In two of the seven locations, there were no differences in rice water weevil levels between winter-flooded and no winter-flooded plots and in one location the inverse trend was seen. The reasons for these differences are unknown. We attempted to have a comparable planting date, rice variety, water depth, proximity to overwintering sites, etc. between the two paired fields at a research site, but this was not always possible. Rice water weevil populations are historically nonuniform across a field and this also makes the research more difficult. Overall, more research needs to be conducted to more clearly understand the relationship between winter-flooding and rice water weevil populations. Results in 1999 were promising enough to justify us continuing our interest in this area.

Body of Report

a. Introduction: The Rice Water Weevil (*Lissorhoptrus oryzophilus* Kuschel) is the most important insect pest of rice in California. Although initially found in California in 1959 in only a relatively small geographical area (Lange and Grigarick 1959), this insect quickly spread throughout the Sacramento Valley rice production region. The spread was about 20 miles per year (Grigarick 1992). Rice is an important agricultural crop in California with about 500,000 acres per year and a total value of $4-5 billion per year (California Rice Promotion Board 1990). In the Sacramento Valley, the economies of many communities depend heavily on rice production. The poorly drained clay soils and environmental conditions in these areas limit cropping possibilities to only a few crops with rice being ideally suited. In California, rice yield losses of 10-30% from rice water weevil infestations can occur. This is the only insect that generally reaches damaging levels in California rice.

The rice water weevil (RWW) in California originated from the southern states rice production area. However, there are several differences between the pest and pest severity between the two production areas. Due to significant differences in rice production systems and regional populations of rice water weevil, geographic specific research is required to include the spectrum of differences known to exist. The differences include: 1.) the variation in the biology of the major insect pest, i.e., rice water weevil reproduces by sexual means in Arkansas, Louisiana, Texas but in California only females are present and reproduction is parthenogenic; and, rice water weevil have 2 to 3 generations per year in Louisiana, one generation and a partial second in Arkansas and Texas, and one generation per year in California; 2.) the diversity and importance of other rice arthropod pests, i.e., rice stink bug, armyworms, rice stalk borer, rice seed midges in Arkansas, Louisiana, and Texas, and rice seed midges, tadpole shrimp, and armyworms in California); 3.) rice water weevil larval density causing economic damage in Louisiana and Texas is 5 per core sample, 10 larvae per core in Arkansas, and one larvae per plant in California); 4.) the method of rice establishment, i.e., in areas of Louisiana and all of California seed is applied directly into the water, whereas in Arkansas, Texas, and areas of Louisiana seed is placed directly into soil and with permanent flood applied approximately 5 weeks later.

In California, this pest overwinters as an adult in a diapause state. As the spring temperatures increase, the weevils break the diapause and eventually (during April to June) fly to and infest newly-flooded rice fields. Those fields with rice plants emerging through the water are most susceptible to infestation. The adults feed on the leaves of rice plants which results in characteristic longitudinal feeding scars. This feeding has no effects on rice growth or yield; however, coinciding with this the adults oviposit in the rice leaf sheaths found just below the water level. Eggs hatch in 3-5 days; the first instar larvae feed on the leaf tissue for a few days and then drop down through the water and soil to the roots. The remaining portion of the life cycle is spent in the flooded soil of rice fields. The larvae develop through four instars and feed on rice roots causing significant damage. Pupation occurs on the rice roots and new adults emerge in late July. These adults feed to a limited extent on rice leaves, then leave the rice fields for overwintering sites.

Management of rice water weevil in California relies on chemical and cultural controls.

Biological control of this pest is nonexistent. Much research has been conducted on rice host plant resistance to rice water weevil. Thus far, some moderate resistance has been identified and is being incorporated into commercial varieties. This research has not yet reached the end user and does not appear to be a stand-alone management tool.

Chemical control of rice water weevil has relied on carbofuran (Furadan® 5G) since the late 1970's. This has been the only insecticide registered for rice water weevil management. This product has been and still is extremely effective for control of this pest. Carbofuran is used in California, as a pre-flood incorporated treatment, on about 35-40% of the rice acreage; usage in 1994 and 1995 was 62,000 pounds active ingredient each year. This usage figure represents a much higher number of fields because most growers apply carbofuran to the first ~30 feet of the basin nearest the levee (the area of high larval densities). This border treatment results in significant savings to growers and greatly reduces the amount of insecticide going into the rice agroecosystem. Since 1991, the registration of Furadan has been tenuous. Following several extensions, the product was available in 1999 and 2000 is designated as a year to clean-up existing inventory, i.e., no new material will be manufactured.

Two alternatives to Furadan are now registered. Use patterns for these new products, (diflubenzuron [Dimilin®] and lambda-cyhalothrin [Warrior®]) are being refined, but effective rice water weevil management can be obtained. Application of Dimilin and Warrior is after flooding and seeding as compared with the pre-plant incorporated timing with Furadan. The most pressing questions are the application timing with these post-flood materials, Dimilin and Warrior, and of even more importance in terms of this proposal is the question of whether border applications will still be a viable option with post-flood treatments. Diflubenzuron and lambda-cyhalothrin manage rice water weevil by minimizing the deposition of viable eggs; they have no effects on rice water weevil larvae, which is the damaging stage. The optimal timing for diflubenzuron and lambda-cyhalothrin appears to be about the 3-leaf stage. The first two leaves of a rice seedling are below the water surface, therefore there is very little foliage above the water to receive the insecticide. Most of the spray will go into the water. The water movement and mixing/dilution of the toxicant may result in border applications not being a viable option with these post-flood materials. If border treatments cannot be used, insecticide usage for rice water weevil will greatly increase and amount of insecticide going into the rice agroecosystem will be magnified. Dimilin and Warrior are also registered for RWW control in rice grown in the southern U.S. However, they also have a third product, fipronil [Icon®], registered which is applied pre-plant or as a seed treatment. Therefore, they have not been required to make a total switch in their management strategies.

The existing cultural controls are of some utility for management of rice water weevil in California. They are 1.) removal of levee vegetation in the spring which may reduce rice water weevil densities in the adjacent rice basins, 2) dry (drill) seeding rice and 3.) delayed seeding dates. All of these methods present some important environmental, agronomic, or production limitations. Winter-flooding of rice fields is being increasingly used as a means to enhance the degradation of rice straw in lieu of burning. A group of University of California scientists have been studying the influence of straw management techniques on the rice agroecosystm. In these small plots studies, my laboratory has found that winter-flooding reduces populations of rice water weevil. Our research has all been conducted at one study location near Maxwell, and to validate this cultural control technique, studies need to be expanded to a broader area. The additional research will allow us to determine how robust this cultural control tool may be.

b. Materials and Methods:

Objective 1: To investigate the effectiveness of post-flood border insecticide treatments for the management of rice water weevil larvae in California rice.

The efficacy on RWW of Dimilin® 2L and Warrior® 1EC was studied in comparison with standard pre-plant Furadan 5G (and untreated plots) in 10 grower fields in 1999. Four of the sites were in Butte Co., one in Sutter Co., one in Placer Co., and four in Colusa Co. Border versus full-basin treatments of Dimilin and borders only for Warrior were examined at 7 and 3 sites, respectively. At each Dimilin site, the respective treatments were applied to borders only (~50 ft) or entire basins of several acres within individually leveed plots. For Warrior, three field sites were set-up and were located in northern Sacramento Valley as follows: one in Butte, and two in Colusa. The efficacy of Warrior was studied in comparison with Dimilin 2L (1 site only) for controlling a natural RWW infestation. In 1999, the standard pre-plant Furadan 5G application was not used for comparison. All Warrior treatments were applied to borders. At one site a border-levee combination was implemented; at another, Dimilin 2L was applied to borders for comparison. Application timings for both products were based on previous research and were determined to be the 3 leaf stage for Warrior and 5 days after 50% plant emergence through the water (also about the 3 leaf stage) for Dimilin. All applications were made with a fixed wing aircraft at 5-10 GPA.

The following samples were taken in each basin. Dates of seeding, application, and sampling are reported in Table 1. Hand sampling was concentrated at ~10 to 15 feet from the levee so as to have the highest rice water weevil infestation. The question was if the active ingredient in the border treatment would dilute so fast that control would not be achieved in this area.

1. Plant scarring - evaluation of the incidence of rice water weevil scarring on plant leaves and the percentage of the plants with scars on either of the two newest leaves was determined from 100 plants per sample. Evaluations were done 3-4 weeks after seeding and about 1 week after application.

2. Laval numbers - the number of rice water weevil larvae per soil core (4 inch diam. by 6 inch deep) was determined twice, about 6 and 7-8 weeks after seeding. The soil and associated plants were processed to recover the rice water weevil larvae and pupae. A washing-flotation technique was used for this step. Twenty samples were taken per treatment per date.

3. Grain yield - rice grain yield adjusted to 14% moisture was quantified in all basins for the Dimilin studies. Hand-harvest samples, 1 sq. m., were taken in each basin (four per basin). Rice was clipped, the grain was threshed and cleaned of debris, the percentage moisture was determined and the grain was weighed. Appropriate calculations were made. Yield samples were also collected with commercial equipment provided by the grower cooperators (six of the seven locations). Grain was weighed in the field with a

weigh-wagon and percentage moisture was determined with a portable moisture meter.

Objective 2: To demonstrate the effectiveness of a cultural technique, winter rice field flooding, for the management of rice water weevil in California rice.

Set-up for the comparison between winter-flooded and non-flooded fields was done in the fall 1998. The original plan was to find paired (flooded and non-flooded) fields. Again, but to a lesser degree than in 1998, spring precipitation in 1999 resulted in many of the rice fields being "winter-flooded" to some extent. However, we overcame this obstacle and did make significant progress toward this objective as outlined below.

The influence of winter-flooding on rice water weevil populations was examined at seven locations; 3 in Sutter, 1 in Butte and 3 in Colusa counties. Paired fields were located and research was coordinated with the growers. Basins or portions of basins were left untreated for RWW so the research could be conducted. Scarred plant (incidence of rice water weevil scarring on plant leaves and the percentage of the plants with scars on either of the two newest leaves) was determined from 100 plants per sample at ~3-4 weeks after seeding and larval data (number of rice water weevil larvae per 20 soil cores [4 inch diam. by 6 inch deep] per treatment) was determined twice, about 6 and 7-8 weeks after seeding; soil and associated plants were processed using a washing-flotation technique to recover the rice water weevil larvae and pupae.

In addition, we monitored adult RWW overwintering populations by taking soil samples that were 1 sq. ft. by 2 in. deep, 2 to 3 times during the late fall (1998) and winter months (1999). Samples were brought back to UC-Davis and Berlese funnels (heat source on top, light underneath) were used to extract the weevils from the soil.

One of the studies in 1999 was again conducted at the long-term straw management study site near Maxwell (Colusa County). At this site, winter-flooded and non-flooded areas comprise the main plots and straw removal treatments (burning, baling, rolled, and incorporated) are the subplots. We have been collecting data at this location for the past 6 years and the winter-flooding (except in 1998) has consistently reduced rice water weevil larval densities. The straw removal treatments have shown no effects on RWW. In 1999, we sampled the winter-flooded versus non-flooded main plots. This resulted in ~7 acre plots (with 4 replicates).

c. Results:

Objective 1: To investigate the effectiveness of post-flood border insecticide treatments for the management of rice water weevil larvae in California rice.

The application timings were generally good, based on previous years data, in all cases. Dimilin application had a slight effect on plant leaf scarring (Table 2). The primary activity of this product is through sterilization of the females, and some egg mortality, rather than direct larval mortality. We have consistently seen a slight reduction in plant leaf scarring following Dimilin applications. In retrospect, applications may be timed slightly later to facilitate control of late-oviposited eggs. In 1998, oviposition was slanted early compared with later in 1999 (based on an associated ovipostion timing study we conducted with Rice Research Board funding). In 1998, eggs were oviposited primarily from the 3-5 leaf stages. In 1999, significant oviposition started at the 2 leaf stage and continued through the 6 leaf stage. Several eggs were also deposited at the 8+ leaf stage in 1999. The cool spring and early summer in 1999 altered the oviposition cycle. Unfortunately, this information was unknown at the time of application. Over all the sites, the average percentage scarred plants ranged from 7.8% for Dimilin + Warrior (borders) to 30.8% for the Dimilin (12 oz) border treated checks. The average scarred plants in the untreated exceeded the threshold of 10-20% at 48.7%.

Examining data from all the sites, the average larval densities in individual sites ranged from 0.05 larvae per core for Dimilin + Warrior (border) treatment to 7.05 larvae per core for Dimilin (8 oz, broadcast) at one of the Colusa Co. sites. At two of the individual Dimilin sites, RWW numbers were too low to draw sound conclusions. Averaged over locations and two sample dates per site, larval numbers ranged from 1.93 to 2.12 for Dimilin treatments, 1.45 for Furadan, and 3.25 for the untreated (Table 2). The Dimilin + Warrior treatments were the most efficacious (Table 2). Overall in 1999, the average number of larvae exceeded the accepted economic threshold of 1 larva per plant with the exception of the Dimilin + Warrior treatments (Tables 2 and 3). Averaged together, there were no differences between the Dimilin border and broadcast (full basin) treatments with each averaging ~2 RWW per sample. Averaged over all the sites (Table 3) in 1999, RWW populations in all of the Dimilin treatments, used without Warrior, were lower than the untreated fields of 3.25 larvae per core but higher than Furadan at 1.45 larvae per core. Of all the Dimilin treatments, the Dimilin + Warrior tank mix averaged the lowest at 0.50 and 0.86 larva per core for border and broadcast, respectively.

At most sites, the larval counts were higher for the 2nd coring date, indicating that a second Dimilin application may have been required to provide adequate RWW control. For instance, at a Colusa Co. site, data showed about 70% larval control (compared with the untreated) with Dimilin on 17 June and 0% control on 29 June (Table 4). The reason for the contrasting results, as shown with the egg deposition data we collected from this same field, is that a peak in oviposition occurred from 17 May to 23 May (1 day before to 5 days after application). The effectiveness of Dimilin on these eggs was shown in the 17 June larval data. However, oviposition increased again from 28 May to 4 June. The Dimilin active ingredient had dissipated at this time and that is shown by the poor control on 29 June. The larvae arising from these late oviposited eggs would have been too small to be collected by our sampling method from the 17 June samples.

Averaged overall the sites in 1999, all of the Dimilin treated plots had higher hand and machine-harvested yields than Furadan and the untreated control plots (Table 2). This differed from 1998 in which none of the individual Dimilin treatments averaged above Furadan and only 50% averaged above the untreated plots. However, past research has shown that densities need to average ~ 1 larva per plant to warrant control measures, i.e., cause economic loss. In past years we have seen higher than desired RWW levels following Dimilin treatment, but no significant yield losses. In 1999, the overall trend was to see high RWW populations (especially adults) but no obvious effects on rice growth and development. The relatively cool spring and summer in 1999 proved optimal for rice growth in the face of RWW root pruning. However, the long flight period and the cool weather also allowed for a long infestation period of RWW adults. In a year such as this, one application of a short-lived product like Dimilin may not be sufficient to provide acceptable larval control. This was shown in the results from 1999, and also in some of the past years, that the numbers of RWW collected per 2nd core sample were generally higher than in the 1st core samples.

Warrior provides RWW control by killing the adults before oviposition. As in 1998, data collected in 1999 showed the Warrior application significantly reduced the incidence of rice water weevil scarred plants. Averaged over the three locations, 15.3% and 27.1% of the plants were damaged in the Warrior (borders) and Dimilin treated basins, respectively (Table 6). As in the other studies, the Warrior sites showed lower larval counts in the 1st sample than the 2nd date and ranged from 0.1 to 2.9 larvae per core for Warrior 1EC (Butte) in the first and second samples, respectively. Overall, larval counts were higher on the 2nd date than the accepted economic threshold of 1 larva per plant and, with the exception of Colusa East site which had too low counts to reliably evaluate, exceeded this threshold for the 1999 season. The Warrior averaged 1.23 larvae per core for border treatment compared with 1.73 for the Dimilin border treatment, but only two of three had high RWW infestations.

As mentioned in the Dimilin result section, in 1999, the overall trend was to see high RWW populations (especially adults) but no obvious effects on rice growth and development. The relatively cool spring and summer in 1999 proved optimal for rice growth in the face of RWW root pruning. However, the long flight period and the cool weather also allowed for a long infestation period of RWW adults. In a year such as this, one application of a short-lived product like Warrior may not be sufficient to provide acceptable larval control.

In summary, the border application appears to have performed as well as a full basin treatment. However, there are still some questions regarding the best way to use Warrior. RWW larvae arising from "late-oviposited" eggs may not have a significant effect on rice plant growth and yield. The larger plant size and root system at the time of feeding may allow the plants to withstand this damage.

Objective 2: To demonstrate the effectiveness of a cultural technique, winter rice field flooding, for the management of rice water weevil in California rice.

Results from the Straw Project site were more favorable in 1999 than in 1998 (year of high precipitation and unwanted flooding). The winter flooded basins compared with the non-flooded basins showed a 62.5% reduction in RWW populations (Table 7). Leaf scarring was also slightly reduced by the winter flooding. These results are very similar to previous years with the exception of 1998.

For the other 6 sites, spring soil dampness delayed soil preparation operations somewhat as in 1998. Therefore, some of our paired field sites have different planting dates, which can sometimes affect RWW populations. Overall, there were no differences among the sites with regards to average number of overwintering adults and RWW per core sample (2.2 vs. 2.8 RWW per core sample) (Table 8). Percentage scarred plants were reduced by the winter-flooding. Looking the data more closely shows that four out of 7 sites had a significantly lower number of RWW larvae in the winter-flooded plots compared with the nonflooded. plots (Table 9). The RWW reduction due to winter-flooding was as high as 80% and was present in two sites that had very high larval populations. In two of the seven locations, there were no differences in RWW levels between winter-flooded and no winter-flooded plots and in one location the inverse trend was seen.

d. Discussion:

Objective 1: To investigate the effectiveness of post-flood border insecticide treatments for the management of rice water weevil larvae in California rice.

In summary, both products (Dimilin® and Warrior®) appear to have potential to effectively control rice water weevil with border treatments. Timing is very critical with these products and will be a challenge for PCAs and growers. The post-flood application timing is new for California rice and there is certainly more to learn about optimizing the timing. If the border treatment strategy is accepted, this will reduce the cost for the grower and amount of insecticide applied to this aquatic system; these are all positive attributes. One concern and possible confounding factor is that neither Dimilin or Warrior provided optimal RWW larval control in 1999. The environmental conditions were conducive to extended adult survival and egg-laying. This greatly stressed the effectiveness of the short-lived materials. Some growers made multiple applications of these products in 1999. On the positive side, Dimilin in 1999 provided excellent protection of yield and resulted in ~1000 lbs. increase in grain yield over the untreated. This appears to indicate that the late arising RWW larvae are not as damaging to the plant as early populations. All the previous research done with RWW effects on rice yields was done with infestations at the early rice growth stages (since this corresponded with the pre-plant incorporated management strategy).

Objective 2: To demonstrate the effectiveness of a cultural technique, winter rice field flooding, for the management of rice water weevil in California rice.

Results from research towards this objective were not clear-cut. Overall, at five of the eight study sites positive results, in terms of RWW management, were seen from the winter-flooding. These reductions in larval numbers were up to 80% and were present under high RWW pressure at some locations. However, at three locations, no differences were seen or even (at one location) more larvae were seen following winter-flooding vs. no winter-flood. Controlling other extraneous factors, which could influence RWW populations, is challenging when conducting this type of research. Differing planting dates, rice varieties, water depths, weed pressures, basin sizes, availability of RWW overwintering habitats, etc. can be important for determining RWW population levels. Rice water weevil populations are historically nonuniform across a field and this also makes the research more difficult. Overall, more research needs to be conducted to more clearly understand the relationship between winter-flooding and rice water weevil populations. Results in 1999 were promising enough to justify us continuing our interest in this area.

e. Summary and Conclusions:

The efficacy of a modified insecticide strategy and a cultural control technique on rice water weevil (*Lissorhoptrus oryzophilus* Kuschel) was evaluated in field studies. The specific objectives of this work were 1.) to investigate the effectiveness of post-flood border insecticide treatments for the management of rice water weevil larvae in California rice and 2.) to demonstrate the effectiveness of a cultural technique, winter rice field flooding, for the management of rice water weevil in California rice. Researchers, Cooperative Extension personnel, agrichemical company representatives, and rice growers were involved in these studies. Preplant applications of a granular insecticide are the standard method of controlling rice water weevil in California; generally application is made only to the basin borders. Registration of the insecticide used for this treatment, Furadan, is scheduled for cancellation. Two products, Dimilin® 2L and Warrior® 1EC, used as post-flood treatments were registered in 1999. Economic rice water weevil populations generally only occur in the first 30-50 feet of the field adjacent to the levees. Therefore, the standard application method with Furadan is to apply the insecticide only to this area. This method provides effective control and has the positive attributes of reducing the amount of insecticide used, cost, potential exposure, etc.

A key question regarding the use of post-flood products is if they will provide efficacious rice water weevil control when applied only to the borders of the field compared with applications to the entire basins. The optimal timing for these post-flood products is approximately the 3 rice leaf stage. There is very little foliage leaf area to intercept the insecticide at this time; most of the insecticide goes into the water. With a border treatment, the mixing of treated and untreated water may dilute the insecticide concentration and render the application ineffective. Studies for this objective were conducted in ten grower fields (seven with Dimilin and three with Warrior) in 1999. Across seven sites, averages were 3.25 rice water weevil per core sample (untreated), 1.45 (Furadan), 2.03 (Dimilin full basin), and 2.04 (Dimilin border treatment). Control efficacy was generally good in the first larval sample date (~7 weeks after seeding and ~4 weeks after application) and poor in the second larval sample date (~9 weeks after seeding). The spring and early summer in 1999 were characterized by cool temperatures. These conditions were optimal for rice water weevil adult survival and for a prolonged oviposition period (related studies conducted by my laboratory verified this). This resulted in adult populations and, in several cases, significant oviposition after the Dimilin or Warrior application had dissipated. These late deposited eggs in treated and untreated plots were manifested as poor control in the later sampling period. However, in all cases, grain yields were higher in the Dimilin treated areas than in the untreated areas (1000 to 2200 lbs/A for hand harvests and 800 to 1400 lbs./A for commercial harvests). There were no significant differences between the yields with the Dimilin full basin vs. border treatments. The reason for these apparent contrasting results (moderate larval control but excellent protection of yield) may be that the early larval infestation (when the plant is probably most susceptible to damage) was effectively controlled and that the later arising larvae do not appreciably effect the plant. Once the plant and root system have obtained significant size, some root pruning by rice water weevil larvae may not be important in terms of yield reduction. The point (plant growth stage) where this insect goes from a pest to non-pest is unknown. Results were generally similar for Warrior treated areas although studies were conducted at only three locations. In summary, it is significant that the border applications of Dimilin or Warrior appear to work as well as full basin treatments. However, it also appears that during years with prolonged oviposition, multiple application of these products may be needed for optimal larval control.

Cultural controls are presently also used, in part, to manage rice water weevil populations. Previous small plot research has shown that lower rice water weevil larval populations occur during the growing season in areas that were winter-flooded compared with non-flooded areas. This research in 1999 was extended to larger plots and to grower fields. Seven locations, comparing rice water weevil populations in paired fields (one winter-flooded and one not winter-flooded), were examined. In addition, research was continued at a large plot research site. Rice plants were evaluated for rice water weevil adult feeding incidence and larval population density. Results from the large plot research site showed a 62.5% reduction in rice water weevil larval populations in winter-flooded basins compared with the non winter-flooded basins. For the other seven grower field sites, overall there were no differences among the sites with regards to average number of overwintering adults and rice water weevil per core sample (2.2 vs. 2.8 RWW per core sample). Percentage scarred plants were reduced by the winter-flooding. However, in four of seven sites, a significantly lower number of larvae was found in the winter-flooded plots compared with the nonflooded. plots. The larval population reduction due to winter-flooding was as high as 80% and was present in two sites that had very high larval populations. In two of the seven locations, there were no differences in rice water weevil levels between winter-flooded and no winter-flooded plots and in one location the inverse trend was seen. The reasons for these differences are unknown. We attempted to have a comparable planting date, rice variety, water depth, proximity to overwintering sites, etc. between the two paired fields at a research site, but this was not always possible. Rice water weevil populations are historically nonuniform across a field and this also makes the research more difficult. Overall, more research needs to be conducted to more clearly understand the relationship between winter-flooding and rice water weevil populations. Results in 1999 were promising enough to justify us continuing our interest in this area.

References

California Rice Promotion Board. 1990. California rice industry economic white paper, Yuba City, CA, 22 pp.

Grigarick, A. A. 1992. Study of the rice water weevil past, present, and future in the United States with emphasis on California. International workshop on establishment, spread, and management of the rice water weevil and migratory rice pests in east Asia. pp. 12-31.

Kisimoto, R. 1992. Spread and management of rice water weevil, an imported insect pest of rice. International Workshop on establishment, spread, and management of the rice water weevil and migratory rice pests in east Asia. pp. 32-41.

Lange, W. H. and A. A. Grigarick. 1959. Rice water weevil. Beetle pest in rice growing areas of southern states discovered in California. Calif. Agric. 13: 10-11.

List of Publications Produced

No journal publications have been produced from this project to date. Reference has been made to these studies in several trade magazine articles. Presentations were made utilizing a portion of these data at the four Winter Rice Production meetings. Data from this project were reported to rice growers at the Rice Field Day on 25 August 1999 in the form of oral presentations and posters and abstracts were published as listed below. Approximately ~500 rice growers and industry personnel attend this field day.

Cuneo, T. D., A. J. Bonacci and L. D. Godfrey. 1999. Sampling rice water weevil with light traps: Can we use this tool to schedule treatments? Calif. Rice Experiment Station Field Day Report. pp 4-5.

Godfrey, L. D. and T. D. Cuneo. 1999. Efficacy of new products for rice water weevil management. Calif. Rice Experiment Station Field Day Report. pp 47-50.

Godfrey, L. D., T. D. Cuneo, and C. L. Alexander. 1999. Post-flood treatments for rice water weevil: Maximizing efficacy. Calif. Rice Experiment Station Field Day Report. pp 6-7.

Godfrey, L. D., T. D. Cuneo, and C. L. Alexander.2000. Refined understanding of rice water weevil biology to optimize management efficacy. 28th Rice Technical Working Group Report, in press.

Appendices

Table 1. Key dates for Objective 1 studies.

County	Study	Plot* Size(A)	Seeding	Application	Scar Counts	RWW immatures 1st Date	RWW immatures 2nd Date	Hand Harvest	Machine Harvest
Sutter	**Dimilin**	112.0	11-May	29-May	2-Jun	30-Jun	9 -Jul	5-Oct	26-Oct
Placer	"	95.3	5-May	20-May	25-May	22-Jun	2-Jul	30-Sep	2-Oct
Colusa-1	"	75.7	25-Apr	18-May	24-May	17-Jun	29-Jun	26-Sep	na
Colusa-2	"	55.7	30-Apr	24-May	27-May	15-Jun	25-Jun	7-Oct	20-Oct
Butte-1	"	81.0	4-May	21-May	26-May	25-Jun	6-Jul	23-Sep	24-Sep
Butte-2	"	95.3	17-May	26-May	1-Jun	24-Jun	7-Jul	27-Sep	29-Sep
Butte-3	"	95.4	30-Apr	18-May	24-May	21-Jun	1-Jul	24-Sep	25-Sep
Colusa-1	**Warrior**	220.0	1-May	15-May	24-May	15-Jun	25-Jun	na	na
Colusa-2	"	101.0	23-Apr	19-May	24-May	15-Jun	25-Jun	na	na
Butte	"	222.6	27-Apr	12-May	17-May	16-Jun	1-Jul	na	na

*grower overall acreage approximated

Table 2. Overall average RWW per core, scarred plants, estimated hand and machine harvest yields - grower fields, Sacramento Valley, Dimilin 2L, 1999.

Treatment	% Scarred Plants	RWW per Core Sample	Hand Yields (lb/acre)*	Machine Yields (lb/acre)*
Dimilin (8 oz) border	24.1	2.00	10290.3	8493
Dimilin (8 oz) broadcast	25.7	2.12	11387.3	9302
Dimilin (12 oz) border	30.8	2.07	11208.1	8567
Dimilin (12 oz) broadcast	23.8	1.93	10519.3	8739
Dimilin + Warrior (border)	7.8	0.50	11724.8	8983
Dimilin + Warrior (broadcast-2 sites only)	14.5	0.86	10452.5	9059
Furadan 5G	17.8	1.45	9940.4	7720
Untreated	48.7	3.25	9562.1	7984

* Yields corrected to 14 % moisture.

Table 3. Overall average % scarred plants and RWW- Dimilin 2L grower field studies, 1999.

Treatment	Application	% Scarred Plants	RWW per Core Sample
Dimilin	broadcast	25.0	2.03
Dimilin	borders	28.0	2.04
Dimilin+Warrior	both	9.4	0.57
Furadan	borders, pre-plant	17.0	1.45
Untreated	-----	49.0	3.25

Table 4. Efficacy of Dimilin application over time against RWW at a Colusa Co. location[a].

	RWW Larvae per Core Sample	
Treatment	17-June Sample Date	29-June Sample Date
Dimilin, (8 oz.) border	2.5	5.25
Dimilin, (8 oz.) full	3.85	10.25
Dimilin, (12 oz.) border	3.2	5.7
Dimilin, (12 oz.) full	1.2	3.4
Furadan 5G	1.5	5.25
Untreated	6.4	4.45

[a] 24 April seeding date and 18 May application date.

Table 5. Overall average RWW per core and scarred plants - grower fields, Sacramento Valley, Warrior 1EC, 1999.

Treatment	% Scarred Plants	RWW per Core
Warrior borders only	19.5	0.97
Warrior borders + levee*	7.0	1.75
Dimilin 2L (12oz) borders*	27.1	1.73

* only 1 site

Table 6. Efficacy of Warrior application over time against RWW.

	RWW per Core Sample		
Warrior Border Treatment	Butte Co. Site	Colusa Co. West Site	Colusa Co. East Site
1st Sample Timing	0.1	1.45	0.6
2nd Sample Timing	2.9	2.05	0.3

Table 7. Scar incidence and larval density data from straw management study – Colusa County.

Treatment	% Scarred Plants	RWW per Core Sample
Winter-flooded	14.5	1.65
No winter-flood	20.5	4.4

Table 8. Overwintering adults, scar incidence and larval density data from winter-flooding study – Grower fields, averaged over Sutter, Butte and Colusa counties.

Treatment	Overwintering adults per core sample	% Scarred Plants	Rice Water Weevil per Core Sample
Winter-flooded	5.6	29.0	2.2
No winter-flood	7.1	48.6	2.8

Table 9. Larval density data from winter-flooding study in grower fields - comparison of sites where winter flooding was effective vs. ineffective.

	Rice Water Weevil per Core Sample	
Treatment	Winter-flooded	No winter-flood
Effective		
Sutter Co. site 1	0.2	1.0
Sutter Co. site 2	0.4	1.8
Colusa Co. site 1	3.3	8.8
Colusa Co. site 2	1.2	5.2
Ineffective		
Sutter Co. site 3	2.2	2.6
Sutter Co. site 4	6.9	5.3
Colusa Co. site 3	4.7	1.9